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Shigehisa Becchaku
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[Inventor]
[Address or Residence] c/o NIPPON SHEET GLASS CO., LTD. 7-28, Kitahama 4-chome, Chuo-ku, Osaka-shi, Osaka
[Name] Shogo KIYOTA
[Inventor]
[Address or Residence] c/o NIPPON SHEET GLASS CO., LTD. 7-28, Kitahama 4-chome, Chuo-ku, Osaka-shi, Osaka
[Name] Shunji WADA
[Inventor]
[Address or Residence] c/o NIPPON SHEET GLASS CO., LTD. 7-28, Kitahama 4-chome, Chuo-ku, Osaka-shi, Osaka
[Name] Yukihiro KATOH
[Inventor]
[Address or Residence] c/o NIPPON SHEET GLASS CO., LTD. 7-28, Kitahama 4-chome, Chuo-ku, Osaka-shi, Osaka
[Name] Naoki KINUGASA
[Applicant]
[Identification No.] 000004008
[Name] NIPPON SHEET GLASS CO., LTD.
[Represented by]
[Identification No.] 100081880
[Patent Attorney] Toshihiko WATANABE
[Telephone] 03(3580)8464
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SUBSTRATE WITH TRANSPARENT CONDUCTIVE FILM AND ORGANIC ELECTROLUMINESCENT DEVICE USING THE SUBSTRATE WITH TRANSPARENT CONDUCTIVE FILM

[Claims for the Patent]

[Claim 1]

A substrate with a transparent conductive film having said transparent conductive film formed thereon, characterized in that surface smoothness Rz of said transparent substrate satisfies 0 nm ≤ Rz ≤ 4 nm.

[Claim 2]

The substrate with a transparent conductive film according to claim 1, characterized in that a surface of said transparent substrate is not polished.

[Claim 3]

The substrate with a transparent conductive film according to claim 1, characterized in that, if said surface of said transparent substrate is polished, said polished transparent substrate is washed by using a mixed liquid of sulfuric acid and ascorbic acid and/or hydrofluoric acid.

[Claim 4]

The substrate with a transparent conductive film according to any one of claims 1 to 3, characterized in that said transparent substrate is washed by using an alkaline liquid after being washed by using an acidic liquid.

[Claim 5]

The substrate with a transparent conductive film according to any one of claims 1 to 4, characterized in that a surface smoothness Rz of said formed transparent conductive film satisfies 0 nm ≤ Rz ≤ 8 nm.

[Claim 6]

An organic electroluminescent device characterized by having the substrate with a transparent conductive film according to any one of claims 1 to 5.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a substrate with a transparent conductive film and an organic electroluminescent (hereinafter referred to as EL) device using the substrate with a transparent conductive film, and in particular, to the substrate with a transparent conductive film including a transparent substrate on which a transparent conductive film to be used as an anode is formed and the organic EL device using the substrate with a transparent conductive film.

[0002]

[Conventional Art]

Organic EL devices, which generally use a transparent substrate such as a glass substrate having a transparent conductive film formed thereon as an anode, are attracting attention as flat surface light sources and light sources of next-generation flat panel displays. A material having a high transmissivity to light and low resistance is used for the transparent conductive film; for instance, indium tin oxide (hereinafter referred to as "ITO"), which is comprised of indium oxide (In_2O_3) having tin (Sn) added thereto, is known. In such an organic EL device, holes injected in from the anode and electrons injected in from a cathode reach a light-emitting layer via a hole transport layer and an electron transport layer respectively, and these holes and electrons recombine in the light-emitting layer whereby emission of light is realized.

[0003]

However, with the conventional organic EL device, if height differences on the surfaces of the anode (i.e. surface undulations) are large, then an electric field may be concentrated at the projecting parts and hence the

EL device may fail and result in non-luminescent spots (spots on the surfaces of the device where light is not emitted), or the projecting parts may short with the cathode and result in non-luminescent spots. If such phenomena occur, then the durability of the organic EL device will drop markedly, and hence the substrate with a transparent conductive film (ITO film) as the anode is required to have excellent smoothness.

[0004]

A glass substrate normally has the surface thereof polished by using a polishing agent to remove waviness and so on arising during the manufacture. During the polishing, the surface may be scratched by the polishing agent, polishing waste and the like, and the polishing agent may remain on the surface. If an ITO film is formed on such a glass substrate that has been scratched or has the polishing agent remaining thereon, then the scratches or the polishing agent will affect the smoothness of the ITO film so that local projecting parts will be produced. It thus becomes necessary to polish the surface of the ITO film.

[0005]

[Problems to be Solved by the Invention]

However, if the surface of the ITO film is polished by using a polishing agent, a polishing pad and the like, then the ITO film will be scratched by the polishing agent or foreign matter that has got in between the glass substrate and the polishing pad. As a result, there has been a problem of non-luminescent spots or the like arising during the manufacture of the organic EL devices, thereby dropping the yield. Moreover, the necessity of having a polishing step for the surface of the ITO film has also resulted in an increase in costs.

[0006]

It is an object of the present invention to provide a substrate with a transparent conductive film and an organic electroluminescent device using the substrate with a transparent conductive film that can improve the durability without generating the non-luminescent spots and reduce the costs.

[0007]

[Means for Solving the Problems]

To attain the object, a substrate with a transparent conductive film having a transparent conductive film formed thereon as claimed in claim 1, characterized in that surface smoothness Rz of the transparent substrate satisfies 0 nm ≤ Rz ≤ 4 nm.

[0008]

According to the substrate with a transparent conductive film as claimed in claim 1, the surface smoothness Rz of the transparent substrate satisfies 0 nm ≤ Rz ≤ 4 nm. Therefore, it is possible to improve the durability without generating the non-luminescent spots and reduce the costs.

[0009]

The substrate with a transparent conductive film as claimed in claim 2, characterized in that a surface of the transparent substrate is not polished.

[0010]

According to the substrate with a transparent conductive film as claimed in claim 2, the surface of the transparent substrate is not polished. Therefore, the polishing step for the surface of the transparent substrate is not necessary, which can improve production efficiency.

[0011]

The substrate with a transparent conductive film as

claimed in claim 3, in the substrate with a transparent conductive film as claimed in claim 1, characterized in that, if the surface of the transparent substrate is polished, the polished transparent substrate is washed by using a mixed liquid of sulfuric acid and ascorbic acid and/or hydrofluoric acid.

[0012]

According to the substrate with a transparent conductive film as claimed in claim 3, if the surface of the transparent substrate is polished, the polished transparent substrate is washed by using a mixed liquid of sulfuric acid and ascorbic acid and/or hydrofluoric acid. Therefore, it is possible to effectively remove scratches, a polishing agent and the like on a glass substrate.

[0013]

The substrate with a transparent conductive film as claimed in claim 4, in the substrate with a transparent conductive film as claimed in any one of claims 1 to 3, characterized in that the transparent substrate is washed by using an alkaline liquid after being washed by using an acidic liquid.

[0014]

According to the substrate with a transparent conductive film as claimed in claim 4, the transparent substrate is washed by using an alkaline liquid after being washed by using an acidic liquid. Therefore, it is possible to further exert the effects of the substrate with a transparent conductive film as claimed in any one of claims 1 to 3.

[0015]

The substrate with a transparent conductive film as claimed in claim 5, in the substrate with a transparent conductive film as claimed in any one of claims 1 to 4, characterized in that the surface smoothness Rz of the

formed transparent conductive film satisfies 0 nm ≤ Rz ≤ 8 nm.

[0016]

According to the substrate with a transparent conductive film as claimed in claim 5, the surface smoothness Rz of the formed transparent conductive film satisfies 0 nm ≤ Rz ≤ 8 nm. Therefore, it is possible to further exert the effects of the substrate with a transparent conductive film as claimed in any one of claims 1 to 4.

[0017]

To attain the object, an organic electroluminescent device as claimed in claim 6 characterized by having the substrate with a transparent conductive film as claimed in any one of claims 1 to 5.

[0018]

According to the organic electroluminescent device as claimed in claim 6, it has the substrate with a transparent conductive film according to any one of the first to fifth aspects. Therefore, it is possible to prevent manufacturing yield from dropping, improve the durability and reduce the costs.

[0019]

[Embodiments of the Invention]

The present inventors carried out assiduous studies to attain the object, and as a result discovered that, in the case of a substrate with a transparent conductive film having a transparent conductive film formed on a transparent substrate manufactured without polishing a surface thereof, if surface smoothness Rz of the transparent substrate satisfies 0 nm ≤ Rz ≤ 4 nm, it is possible to improve durability without generating non-luminescent spots and reduce costs. They further discovered that, in the case of an organic

electroluminescent (EL) device having the substrate with a transparent conductive film, it is possible to prevent manufacturing yield from dropping, improve the durability and reduce the costs.

[0020]

Embodiments of the present invention will be described below with reference to the drawings.

[0021]

Figure 1 is a schematic sectional view showing a construction of the organic EL device according to an embodiment of the present invention.

[0022]

In Figure 1, an organic EL device 10 is comprised of an ITO film-formed substrate 4 that is comprised of a glass substrate 1 (transparent substrate) made of soda lime or the like, a silicon oxide film (SiO_2 film) 2 that is formed on a surface of the glass substrate 1 and is for alkaline passivation, and a transparent conductive film (ITO film) 3 that is formed on the surface of the SiO_2 film 2, a hole transport layer 5 that is formed on the surface of the ITO film 3 and is for efficiently injecting holes into a light-emitting layer 6, a thin metallic film layer 7 that is formed on the surface of the hole transport layer 5 and is for injecting electrons into the light-emitting layer 6, and the light-emitting layer 6 which emits light by recombining the injected holes and electrons. A direct current voltage is applied between the ITO film 3 and the thin metallic film layer 7 by using a variable direct current power source.

[0023]

The hole transport layer 5 and the light-emitting layer 6 are both made of an organic material. As the organic material constituting the hole transport layer 5, TPD (triphenyl diamine) or m-MTDATA (4,4',4"-tris-(N-(3-methylphenyl)-N-phenylamino) triphenylamine for instance)

is used. Moreover, the light-emitting layer 6 is made of a parent material containing a dopant, and as the organic material constituting the parent material, for instance, an aluminum quinolinol complex or DPVBi (4,4'-bis(2, 2'-diphenylvinyl)-biphenyl for instance) can be used. As the metallic material constituting the thin metallic film layer 7, a metallic material such as Al, Mg, In, Ag, In-Li, Mg-Sr or Al-Sr can be used.

[0024]

With the organic EL device 10 constituted as described above, taking the ITO film 3 as an anode and the thin metallic film layer 7 as a cathode, if a direct current voltage is applied between the ITO film 3 and the thin metallic film layer 7, then holes from the ITO film 3 reach the light-emitting layer 6 via the hole transport layer 5. And when electrons from the thin metallic film layer 7 reach the light-emitting layer 6, these holes and electrons recombine in the light-emitting layer 6, whereby light is emitted mostly in the direction of an arrow A in Figure 1.

[0025]

However, if there are marked surface undulations on the ITO film-formed substrate 4 as the anode, i.e. surface height differences are large, then an electric field may be concentrated at the projecting parts. Therefore, small electrical discharges may occur, and thus the organic EL device 10 itself may fail or non-luminescent spots may arise, i.e. the durability of the organic EL device 10 will be markedly reduced. Consequently, to maintain a good light emission state and improve the durability, the surface of the ITO film-formed substrate 4 is required to have as small surface height differences as possible, i.e. an excellent value of Rz (10-point mean roughness), which represents the surface smoothness. The surface smoothness Rz is the

difference between the mean value of the heights of the highest to fifth highest peaks over a sampled portion relative to a reference height, and the mean value of the heights of the deepest to the fifth deepest troughs over the sampled portion relative to the reference height.

[0026]

According to the present embodiment, the surface smoothness Rz of the ITO film-formed substrate 4 significantly influences the surface smoothness Rz of the glass substrate 1. Thus, to improve the surface smoothness Rz of the ITO film-formed substrate 4, the surface smoothness Rz of the glass substrate 1 was set to $0\ nm \leq Rz \leq 4\ nm$. Local projections arise on the surface of the glass substrate 1 due to a polishing agent (e.g. cerium oxide powder) and/or polishing waste remaining after a polishing step for polishing the surface of the glass substrate 1, and scratches and the like arising on the surface through the polishing. Therefore, the glass substrate 1 was prepared without polishing the surface in the polishing step. As a result of this, it was discovered that the surface smoothness Rz of the prepared glass substrate 1 is $0\ nm \leq Rz \leq 4\ nm$.

[0027]

According to the present embodiment, it was discovered that it is possible, even after polishing the surface of the glass substrate 1, to wash it by using a mixed liquid of sulfuric acid and ascorbic acid and/or hydrofluoric acid and thereby remove the scratches, polishing agent and the like remaining on the surface of the glass substrate 1 after the polishing step so as to set the surface smoothness Rz to $0\ nm \leq Rz \leq 4\ nm$. Similarly, it was discovered that it is also possible to set the surface smoothness Rz of the glass substrate 1 to $0\ nm \leq Rz \leq 4\ nm$ by washing the surface of the polished glass substrate 1 by using an alkaline liquid after

washing it by using an acidic liquid such as hydrofluoric acid.

[0028]

Furthermore, as a result of making the ITO film-formed substrate 4 by using the glass substrate 1 of which surface smoothness Rz is set to $0 \text{ nm} \leq Rz \leq 4 \text{ nm}$ and examining the surface thereof, a very smooth ITO film-formed substrate 4 with no local projection was obtained within the range of $0 \text{ nm} \leq Rz \leq 8 \text{ nm}$.

[0029]

The parent material glass of the glass substrate 1 may have been manufactured by any manufacturing method, so long as it is sheet glass. For instance, the sheet glass manufactured by a float process in which the sheet glass is formed to a predetermined thickness on a molten metal is preferable.

[0030]

In the float process, raw materials are mixed together to form a predetermined composition and are put into a melting furnace, and melting and homogenization are carried out at a high temperature over a long time period in the melting furnace. Next, the molten glass is poured onto molten metal (tin (Sn)) in a forming bath that has a hermetically sealed structure containing a reducing atmosphere so as to be formed to a predetermined thickness. After that, cooling is carried out down to room temperature in an annealing furnace while preventing warping. With this sheet glass production method, the sheet glass is formed to a predetermined thickness on molten metal, and hence high-quality glass that is excellent in terms of uniformity of thickness and smoothness can be continuously produced in large amounts, and hence productivity thereof is extremely high.

[0031]

Next, a description will be given as to a method of

manufacturing the ITO film-formed substrate 4 in Figure 1.

[0032]

Figure 2 is a view of the internal structure of an ion plating apparatus used in the manufacture of the ITO film-formed substrate 4 in Figure 1.

[0033]

In Figure 2, reference numeral 11 denotes a glass substrate made of soda lime or the like. A vacuum vessel 18, which acts as a film deposition chamber, has an exhaust port 19 provided in a side wall on the one side thereof, and has a tubular part 20 provided in a side wall on the other side thereof. A pressure gradient type plasma gun 22 is installed in the tubular part 20, and a converging coil 21 is provided surrounding the tubular part 20.

[0034]

The plasma gun 22 is comprised of a second intermediate electrode 24 that has an electromagnetic coil 23 built therein and is connected to the tubular part 20, a first intermediate electrode 26 that has a ring permanent magnet 25 built therein and is provided parallel to the second intermediate electrode 24, a cathode 27, and a cylindrical glass tube 28 that is interposed between the cathode 27 and the first intermediate electrode 26.

[0035]

The electromagnetic coil 23 is excited by a power source 29, and the converging coil 21 is excited by a power source 30. The power source 29 and the power source 30 are both made to be variable power sources.

[0036]

The second intermediate electrode 24 and the first intermediate electrode 26 are connected to one end (the positive side) of a variable voltage type main power source 33 via suspended resistors 31 and 32 respectively,

and the cathode 27 is connected to the other end (the negative side) of the main power source 33. Moreover, an auxiliary discharge power source 34 and a suspended resistor 35 are connected in parallel with the main power source 33 via a switch 36.

[0037]

Moreover, a cylindrical member 37 that is made of Mo (molybdenum) and is fixed to the cathode 27, a pipe 38 that is made of Ta (tantalum), and a disk-shaped member 39 that is made of LaB_5 and is fixed to the cylindrical member 37 in front of the pipe 38, are provided inside the glass tube 28, and a discharge gas (e.g. Ar gas containing a predetermined amount of oxygen) is fed into the plasma gun 22 via the pipe 38 in the direction of the arrow B.

[0038]

A main hearth 41 housing an ITO sintered body 40 as a tablet (a substance to be evaporated) is provided in a bottom portion of the vacuum vessel 18, and moreover an auxiliary hearth 42 is provided surrounding the main hearth 41. The main hearth 41 is made of an electrically conductive material having good thermal conductivity, such as copper, and has formed therein a recess into which a plasma beam from the plasma gun 22 is fired, and is further connected to the positive side of the main power source 33 to form an anode, thus attracting the plasma beam.

[0039]

As with the main hearth 41, the auxiliary hearth 42 is also made of an electrically conductive material such as copper having good thermal conductivity. A ring permanent magnet 43 and an electromagnet 44 are housed in the auxiliary hearth 42, and the electromagnet 44 is excited by a hearth coil power source 45 which is a variable power source. To be more specific, the

auxiliary hearth 42 has the construction in which the ring permanent magnet 43 and the electromagnet 44 are provided on top of one another coaxially within the same annular vessel which surrounds the main hearth 41, and also the electromagnet 44 is connected to the hearth coil power source 45, and thus a magnetic field formed by the ring permanent magnet 43 and a magnetic field formed by the electromagnet 44 are superimposed on one another. In this case, the direction of the magnetic field on the inside generated by the ring permanent magnet 43 and the direction of the magnetic field on the inside from the electromagnet 44 are the same. And it is possible to vary the current supplied to the electromagnet 44 by varying the voltage of the hearth coil power source 45.

[0040]

Moreover, as with the main hearth 41, the auxiliary hearth 42 is also connected to the positive side of the main power source 33 via a suspended resistor 46 to form an anode.

[0041]

Furthermore, a heater 47 is provided in an upper portion of the vacuum vessel 18, and the glass substrate 10 is heated to a predetermined temperature by using the heater.

[0042]

With the ion plating apparatus constructed as described above, if the ITO sintered body 40 having a tin oxide (SnO_2) content of 4 to 6 mass % is housed in the recess of the main hearth 41, and a discharge gas is fed through the pipe 38 from the cathode 27 side of the plasma gun 22, then a discharge is generated between the plasma gun 22 and the main hearth 41, whereby a plasma beam is produced. The plasma beam is converged by the ring permanent magnet 25 and the electromagnetic coil 23, and is then guided by a magnetic field determined by the

converging coil 21 and by the ring permanent magnet 43 and the electromagnet 44 inside the auxiliary hearth 42, and thus reaches the main hearth 41.

[0043]

The ITO sintered body 40 housed in the main hearth 41 is heated by the plasma beam and thus evaporates, and the evaporated particles are ionized by the plasma beam, whereby an ITO film is formed on the glass substrate 11 that is being heated by the heater 47.

[0044]

According to the embodiment described above, the organic EL device 10 is comprised of an ITO film-formed substrate 4 that is comprised of a glass substrate 1, an SiO_2 film 2 that is formed on the surface of the glass substrate 1 and is for alkaline passivation, and an ITO film 3 that is formed on the surface of the SiO_2 film 2, a hole transport layer 5 that is formed on the surface of the ITO film 3 and is for efficiently injecting holes into a light-emitting layer 6, a thin metallic film layer 7 that is formed on the surface of the hole transport layer 5 and is for injecting electrons into the light-emitting layer 6, and the light-emitting layer 6 which emits light by recombining the injected holes and electrons. As the surface smoothness Rz of the glass substrate 1 is $0 \text{ nm} \leq Rz \leq 4 \text{ nm}$, non-luminescent spots do not occur and thus durability can be improved and costs can be reduced. Furthermore, as the organic EL device 10 has the glass substrate 1 of which surface smoothness Rz is $0 \text{ nm} \leq Rz \leq 4 \text{ nm}$, it is possible to prevent manufacturing yield from dropping, improve the durability and reduce the costs.

[0045]

[Examples]

Hereunder, examples of the present invention will be

described.

[0046]

The present inventors prepared ITO film-formed substrates 4 based on glass substrates 1 having different surface smoothnesses Rz and manufacturing conditions, and further prepared organic EL devices 10 from the prepared ITO film-formed substrates 4 (Examples 1 to 7, Comparative Examples 1 to 5).

[0047]

To be more specific, the glass substrates 1 were each washed with a dipping type ultrasonic washing machine by using an alkaline detergent, and then dried in a warm air current. Next, each glass substrate 1 was put into an in-line type vacuum deposition apparatus, heated to approximately 220 °C and exhaustion was carried out, and then Ar gas was introduced, the pressure was adjusted to 0.4 to 0.7 Pa, and an SiO_2 film 2 for alkaline passivation was formed by using radio-frequency magnetron sputtering. Without exposing the glass substrate 1 having the SiO_2 film 2 formed thereon to the atmosphere, an ITO film 3 was then continuously formed by using an ion plating apparatus in Figure 2.

[0048]

Next, each ITO film-formed substrate 4 was put into a vacuum deposition apparatus, exhaustion was carried out down to a pressure of not more than 1.3×10^{-4} Pa, and then triphenyl diamine (TPD) as a hole transport layer 5 and an aluminum quinolinol complex (alq 3) as a light-emitting layer 6 were formed. Subsequently, an MgAg alloy film (Mg:Ag = 10:1), which is a thin metallic film layer 7, was formed on the organic layers as a cathode.

[0049]

Without exposing the prepared organic EL devices 10 to the atmosphere, nitrogen gas was introduced into a vacuum chamber, and the ITO film-formed substrate 4 was

fixed to a glass substrate and sealed with an epoxy resin. The surface smoothnesses Rz of the prepared ITO film-formed substrates 4 were measured by using an atomic force microscope, and a direct current was applied to each of the prepared organic EL devices 10 to evaluate light emission surface characteristics thereof. The results are shown in Table 1.

[0050]

[Table 1]

	Surface smoothness of glass substrate (Rz)	Surface smoothness of ITO film (Rz)	Luminescent characteristic
Example 1	4nm	7nm	No non-luminescent spot exists
Example 2	3nm	6nm	No non-luminescent spot exists
Example 3	2nm	4nm	No non-luminescent spot exists
Example 4	2nm	5nm	No non-luminescent spot exists
Example 5	2nm	7nm	No non-luminescent spot exists
Example 6	1nm	4nm	No non-luminescent spot exists
Example 7	4nm	8nm	No non-luminescent spot exists
Comparative Example 1	8nm	14nm	Non-luminescent spots exist
Comparative Example 2	10nm	17nm	Non-luminescent spots exist
Comparative Example 3	5nm	11nm	Non-luminescent spots exist
Comparative Example 4	5nm	10nm	Non-luminescent spots exist

[0051]

[Example 1]

This example used a soda-lime glass substrate 1 having a surface smoothness Rz of 4 nm that had been prepared by using a float process. The surface smoothness Rz after forming the ITO film was 7 nm, and non-luminescent spots were not found on the organic EL device.

[0052]

[Example 2]

This example used a soda-lime glass substrate 1 having a surface smoothness Rz of 8 nm that had been prepared by using a float process and was subjected to hydrofluoric acid washing and then to alkaline washing to

control the surface smoothness Rz to 3 nm. The surface smoothness Rz after forming the ITO film was 6 nm, and non-luminescent spots were not found on the organic EL device.

[0053]

[Example 3]

This example used a soda-lime glass substrate 1 having a surface smoothness Rz of 4 nm that had been prepared by using a float process and was subjected to hydrofluoric acid washing and then to alkaline washing to control the surface smoothness Rz to 2 nm. The surface smoothness Rz after forming the ITO film was 4 nm, and non-luminescent spots were not found on the organic EL device.

[0054]

[Example 4]

This example used a soda-lime glass substrate 1 that had been prepared by using a float process and had its surface polished by using cerium oxide powder having a mean particle diameter of approximately 1 μm, and was subjected to sulfuric acid and ascorbic acid washing to remove the cerium oxide powder and then to hydrofluoric acid washing and alkaline washing so as to control the surface smoothness Rz to be 2 nm. The surface smoothness Rz after forming the ITO film was 5 nm, and non-luminescent spots were not found on the organic EL device.

[0055]

[Example 5]

This example used a soda-lime glass substrate 1 that had been prepared by using a float process and had its surface polished by using cerium oxide powder having a mean particle diameter of approximately 1 μm and further given a finishing polish by using cerium oxide powder having a mean particle diameter of approximately 0.6 μm, and was then subjected to hydrofluoric acid washing and

alkaline washing so as to control the surface smoothness Rz to 2 nm. The surface smoothness Rz after forming the ITO film was 7 nm, and non-luminescent spots were not found on the organic EL device.

[0056]

[Example 6]

This example used a soda-lime glass substrate 1 that had been prepared by using a float process and had its surface polished by using cerium oxide powder having a mean particle diameter of approximately 1 μm, and was subjected to sulfuric acid and ascorbic acid washing to remove the cerium oxide powder and then to hydrofluoric acid washing and alkaline washing so as to control the surface smoothness Rz to 1 nm. The surface smoothness Rz after forming the ITO film was 4 nm, and non-luminescent spots were not found on the organic EL device.

[0057]

[Example 7]

This example used a soda-lime glass substrate 1 that had been prepared by using a float process and had its surface polished by using cerium oxide powder having a mean particle diameter of approximately 1 μm, and was subjected to sulfuric acid and ascorbic acid washing to remove the cerium oxide powder and then to alkaline washing so as to control the surface smoothness Rz to be 4 nm. The surface smoothness Rz after forming the ITO film was 8 nm, and non-luminescent spots were not found on the organic EL device.

[0058]

[Comparative Example 1]

This example used a soda-lime glass substrate 1 having the surface smoothness Rz of 8 nm that had been prepared by using a float process. The surface smoothness Rz after forming the ITO film was 14 nm, and non-luminescent spots were found on the organic EL device.

[0059]

[Comparative Example 2]

This example used a soda-lime glass substrate 1 that had been prepared by using a float process and had its surface polished by using cerium oxide powder having a mean particle diameter of approximately 1 μm to set the surface smoothness Rz to 10 nm. The surface smoothness Rz after forming the ITO film was 17 nm, and non-luminescent spots were found on the organic EL device.

[0060]

[Comparative Example 3]

This example used a soda-lime glass substrate 1 that had been prepared by using a float process and had its surface polished by using cerium oxide powder having a mean particle diameter of approximately 1 μm and then subjected to hydrofluoric acid washing and alkaline washing to set the surface smoothness Rz to 5 nm. The surface smoothness Rz after forming the ITO film was 11 nm, and non-luminescent spots were found on the organic EL device.

[0061]

[Comparative Example 4]

This example used a soda-lime glass substrate 1 that had been prepared by using a float process and had its surface polished by using cerium oxide powder having a mean particle diameter of approximately 1 μm and further given a finishing polish by using cerium oxide powder having a mean particle diameter of approximately 0.6 μm to set the surface smoothness Rz to 5 nm. The surface smoothness Rz after forming the ITO film was 10 nm, and non-luminescent spots were found on the organic EL device.

[0062]

As shown in the examples 1 to 7 and the comparative examples 1 to 4, the ITO film-formed substrate 4 of 0 nm ≤ Rz ≤ 8 nm or less was acquired by setting (controlling)

the surface smoothness Rz of the glass substrate 1 to 0 nm ≤ Rz ≤ 4 nm, which suppressed occurrence of the non-luminescent spots on the organic EL device 10. It was also discovered that, it is possible, even after polishing the glass substrate 1, to remove the scratches, polishing agent and the like of the glass substrate arising in the polishing step by subjecting it to sulfuric acid and ascorbic acid washing and subsequently to alkaline washing or subjecting it to sulfuric acid and ascorbic acid washing and subsequently to hydrofluoric acid washing and then alkaline washing.

[0063]

According to the examples, the ITO film 3 was formed on the glass substrate 1 by an ion plating method. However, it is not limited thereto but it may also be formed by sputtering or an electron-beam (EB) deposition method.

[0064]

[Advantages of the Invention]

As described in detail above, according to the substrate with a transparent conductive film as claimed in claim 1, the surface smoothness Rz of the transparent substrate satisfies 0 nm ≤ Rz ≤ 4 nm. Therefore, it is possible to improve the durability without generating the non-luminescent spots and reduce the costs.

[0065]

According to the substrate with a transparent conductive film as claimed in claim 2, the surface of the transparent substrate is not polished. Therefore, the polishing step for the surface of the transparent substrate is not necessary, which can improve production efficiency.

[0066]

According to the substrate with a transparent conductive film as claimed in claim 3, if the surface of

the transparent substrate is polished, the polished transparent substrate is washed by using a mixed liquid of sulfuric acid and ascorbic acid and/or hydrofluoric acid. Therefore, it is possible to effectively remove scratches, a polishing agent and the like on a glass substrate.

[0067]

According to the substrate with a transparent conductive film as claimed in claim 4, the transparent substrate is washed by using an alkaline liquid after being washed by using an acidic liquid. Therefore, it is possible to further exert the effects of the substrate with a transparent conductive film as claimed in any one of claims 1 to 3.

[0068]

According to the substrate with a transparent conductive film as claimed in claim 5, the surface smoothness Rz of the formed transparent conductive film satisfies 0 nm ≤ Rz ≤ 8 nm. Therefore, it is possible to further exert the effects of the substrate with a transparent conductive film as claimed in any one of claims 1 to 4.

[0069]

According to the organic electroluminescent device as claimed in claim 6, it has the substrate with a transparent conductive film according to any one of the first to fifth aspects. Therefore, it is possible to prevent manufacturing yield from dropping, improve the durability and reduce the costs.

[Brief Description of the Drawings]

[Figure 1]

Figure 1 is a sectional view schematically showing an organic EL device according to an embodiment of the present invention; and

[Figure 2]

Figure 2 is a view of an internal structure of an ion plating apparatus used in manufacture of an ITO film-formed substrate 4 in Figure 1.

[Description of Symbols]

1, 11 Glass substrates

2 SiO_2 film

3 ITO film

4 ITO film-formed substrate

5 Hole transport layer

6 Light-emitting layer

7 Thin metallic film layer